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The Effects of Statis Stretching on Measures of Gross Motor Coordination During Vigorous Physical Activity

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THE EFFECTS OF STATIC STRETCHING ON MEASURES OF GROSS MOTOR COORDINATION DURING VIGOROUS PHYSICAL ACTIVITY

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ABSTRACT

Static stretching has been linked to lesser performance in many sport activities. The purpose of this study was to assess the effects of static stretching upon gross motor coordination patterns (GMCP) and power and fatigue markers exhibited during vigorous cycling. The performance of 28 females between the ages of eighteen and thirty were analyzed during the Wingate Anaerobic Test (WAnT). Using a counterbalanced design, participants completed the test under two conditions, following static stretching and no stretching. While results showed statistically significant differences ($p \leq 0.05$) between conditions for the assessed dependent variables, no statistically significant differences were found between conditions for measures of peak power (PP), low power (LP), or fatigue index (FI). These findings suggest that while static stretching has no statistically significant effect on measures of power and fatigue, it does subtly influence GMCP exhibited during the WAnT.

Keywords: coordination, power-cadence relationship, critical power, motor control, central pattern generator

Dedicated to my parents

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CHAPTER 1

INTRODUCTION AND BRIEF REVIEW OF LITERATURE

Musculoskeletal injuries due to repetitive activity represent 50% of all injuries nationally. According to the American Academy of Orthopedic Surgeons, this represents an economic cost of $849 billion annually.[1] In 2010, the Department of Defense funded 22.5 million dollars on research aimed at specifically understanding and reducing musculoskeletal injuries of a repetitive nature associated with military combat.[2] From the military to the civilian work force, injuries resulting from repetitive motions - or musculoskeletal disorders (MSD) -- are widely evident. According to the Bureau of Labor Statistics, there were 346,400 MSD cases in 2010 (this statistic was seven percent higher than in 2009). In addition, the BLS found that "musculoskeletal disorders accounted for 29 percent of all workplace injuries and illnesses requiring time away from work in 2010".[3]

Such statistics indicate that MSD are dangerously high, affecting the lives of individuals and the United States as a whole. Numerous studies have linked musculoskeletal disorders to the gross motor coordination patterns (GMCP) used to perform activities.[4] For example, studies have investigated the impact of fatigue on the quality of coordination patterns during gross motor activities and the risk of injury.[5,6] A capacity to maintain muscular performance during high intensity exercise – or to withstand the effects of fatigue – is a central component of gross motor coordination. Fatigue is defined as a state of increased discomfort and decreased efficiency resulting from prolonged or excessive exertion, and the related loss of power or capacity to respond to stimulation.[7] As muscles are exercised, many factors may cause the quality and efficiency of motion to decrease. Among these include pain, exhaustion, and the use of improper technique during the execution of an action.[8,9,10,11]

Similarly, other studies have indicated that static stretching (STST) affects muscular force-generating capacities in subtle ways, and some researchers and clinicians have drawn links between these effects and reduced performance, increased risk of musculoskeletal injury, or both.[12,13]. Static stretching is widely used today within sport, fitness, and rehabilitation programs across the world. It is a relatively gentle form of exercise and some advocate it as a means of reducing injury.[12] Yet studies also link STST to decreased maximal force production and it can negatively impact high intensity physical activities such as sprinting, swimming, or cycling.[14,15,16] Additional studies suggest STST decreases tendon stiffness, which can increase energy consumption during vigorous physical activity.[14,17] Other studies have linked STST techniques to greater stress relaxation of muscle tissue and lesser muscle activation within the central nervous system, thus potentially affecting gross motor coordination patterns during vigorous physical activity.[12]

One such common test of vigorous physical activity is the Wingate Anaerobic Test (WAnT). This test is widely used in laboratory settings, as it measures power output during a maximal 30 second cycling bout, and thus it is widely used for the analysis of anaerobic capacity.[18,19,20,21,22] The WAnT is used to assess anaerobic power in a variety of populations[23] in part due to the wide availability of cycle ergometers, the familiarity of many individuals with pedaling, and the ease of administering this test.[24,25] The WAnT is used to assess a person's ability to produce maximal power while using both the ATP-PCr and anaerobic glycolysis energy systems.[26,8] Consequently, this test is widely used to evaluate muscular power, endurance, and fatigue[19], as it serves to estimate a person's ability to transform power and energy from non-oxygenated energy systems.[21] Measurements commonly taken from the WAnT include peak power output (PPO), mean power output (MPO), and fatigue index (FI).[23] Previous research has shown that these measurements are valuable in assessing a person's anaerobic fitness level and the effects of anaerobic training.[23] It has also been found that a notable relationship exists between power and athletic performance[8] due to the repeated bouts of high intensity effort required during exercise and many sports activities.[8] The WAnT has been used to study a wide variety of topics, such as the anaerobic power characteristics of competitive athletes [27,28, 29, 24,30], the physiological and cognitive responses to maximal exercise[29,21], and the impact of riding position on power output. [24,31] These types of investigations have allowed scientists to develop a deeper understanding of anaerobic performance across a spectrum of populations and within a variety of contexts.

However, little research has been done on GMCP demonstrated during vigorous physical activity, such as the high intensity cycling exhibited during the completion of the WAnT. Research in this area would help to explain how GMCP change due to fatigue during vigorous physical activity. In this vein many studies have linked knee injuries to poor motor control or neuromuscular coordination during gross motor activities,[32] and other studies show evidence that STST has a detrimental effect on maximal muscular force production and control.[14,15,16] Further research is needed on the effects of STST on GMCP measures during vigorous physical activity, as studying the effects of STST on the GMCP demonstrated during a widely used laboratory test of vigorous physical activity may help to explain the ways that fatigue contributes to coordination patterns that lead to MSD.

In summary, few studies exist on the influence of STST on the gross motor coordination patterns of vigorous physical activities requiring high anaerobic power.[33,34,35] Thus, the primary aim of this study was to examine the effects of STST on GMCP exhibited during maximal cycling. This aim was accomplished by having participants complete the WAnT under two riding conditions, after performing a standardized STST protocol and without completing the stretching regimen. Given the numerous studies suggesting STST reduces neuromuscular performance in activities such as sprinting and jumping, which use similar metabolic pathways as the WAnT, we hypothesized that participants would demonstrate lesser laboratory measures of gross motor coordination and anaerobic power during the WAnT, following completion of the standardized STST protocol and when compared to the non-stretching condition.

CHAPTER 2

METHODS

Experimental Approach to the Problem

This study used a quasi-experimental design, as the participants served as their own controls by completing both experimental conditions. A sample of convenience was recruited for participation in this study. The purpose of this study was to investigate the effects of STST on the GMCP of cycling during a widely accepted test of vigorous physical activity, the WAnT. Commonly used statistical testing was conducted as a means of assessing the findings for statistically significant differences and for relevance in practical application.

Participants

Subjects were recruited by means of posting advertisements on the Western Kentucky University campus, e-mailing fellow students, as well as word of mouth (Appendix 1). Inclusion criteria included women between the 18-30 years of age, assessed as low risk on the ACSM risk stratification guidelines, and who regularly exercise (Table 2). Individuals with known lower extremity pathology or who regularly cycle were excluded.

For this study we recruited a total thirty five participants, but some of the participants were not able to complete all testing, and equipment malfunction prompted the research team to exclude additional data from statistical analysis. Thus, the study sample, included twenty-eight women (n=28) between the ages of eighteen and thirty (21.25±2.46 yr; 167.89±5.80 cm; 63.46±7.86 kg).

Instruments

The following instruments were used during the study:

Wingate Anaerobic Test

The WAnT is one of the most widely used scientific methods for assessing anaerobic power.[20,8] Authors have found this instrument valid and reliable for assessing anaerobic capacity in a variety of populations.[21,25,28] The test requires participants to pedal a bicycle for 30 seconds at their maximum effort level against a pre-determined resistance. Upon commencement of the test, administrators assess the revolutions completed in five-second intervals of the total 30 seconds of the test. The WAnT was completed in our study using the Computrainer™, an electronically braked ergometer.

Computrainer™ and Spinscan™ Software

The CompuTrainer™ Lab Pro 3D (RacerMate, Seattle, WA) is an electronically braked ergometer suitable for use in the laboratory or many environments beyond the laboratory. The CompuTrainer™ is a well-known and widely used ergometer that is utilized by cyclists, coaches, and scientists worldwide to help improve cycling technique and performance. Its proprietary software applications, such as the SpinScan Pedal Stroke Analyzer™ allow for detailed analysis of many aspects of cycling performance. Studies have found the CompuTrainer™ to be both valid and reliable when utilized as a bicycle ergometer,[36,37] and it is widely used in peer-reviewed studies.[38,39,40]

The Computrainer™ provides a means of precisely measuring the gross motor coordination within the participants and between the conditions used in this study. The Computrainer and its software were used in this study to measure variables, such as the SpinScan (SS), Average Torque Angle (ATA), revolutions per minute (RPM), wattage (W), and the percentage of relative contribution of the legs under these different conditions.

The Computrainer™ can be administered on a variety of bicycles, including commonly available road and off-road bicycles, and this is one of the appealing aspects of this ergometer, as it allows scientists and coaches to analyze cycling performance on the rider's own bicycle. In our study, participants performed the test on a Serotta Fit Cycle™ (Serotta, Saratoga Springs, New York). The Serotta Fit Cycle™ was utilized to standardize conditions for the non-cyclists who comprised the sample. This instrument allows for easy adjustments to the various heights of our participants yet remains relatively constant between trials. For this study, the seat tube was angled at 78 degrees. Further, the seat was positioned parallel to the ground with the seat height being determined using the method described by Lemond.[41]

American College of Sports Medicine (ACSM) Risk Stratification Index

Risk stratification was determined by the standards set by the American College of Sports Medicine (ACSM). The answers given by the participants to these questions allowed us to establish what risk category (low, moderate, or high) classified each participant. If the participant was determined to be at moderate or high risk, then a medical exam and graded exercise test were required before they could participate in the study. If the participant was at low risk, then a medical exam and graded exercise test were not required prior to participating in the study (Appendix 2).

Procedures

Prior to testing, participants underwent a series of screenings to test for possible exclusion criteria that would prohibit them from engaging in the study. They first answered questions on a detailed medical screening form that determined whether they are at risk for coronary artery disease or showed signs and symptoms of cardiovascular, pulmonary, or metabolic disease (Appendix 2). Under the conditions that the individual completed the screening process, meet the necessary criteria, and was willing to participate, she then read and sign an informed consent document (Appendix 3). The informed consent document was created by the researchers and complies with the federal guidelines set for research pertaining to human subjects and reviewed by the Institutional Review Board at Western Kentucky University. The individuals voluntarily participated in this study and were aware that they would not receive compensation for their time.

Each participant visited the laboratory on two occasions. The participant's heart rate, blood pressure, and respiratory rate were taken at the onset of each laboratory session. Following assessment of resting vitals, the participants performed one of two conditions: stretching (STST) or control (NS). The order for these two conditions was determined by a counterbalanced design. The STST protocol (Appendix 7 & 8) used in this investigation was patterned after those used in previous studies on static stretching, consisting of four, 30-second repetitions each of 5 stretching exercises, which were performed with an average total stretching time of 20 minutes, [42] and included stretches for the hip extensors, hip flexors, knee flexors, and knee extensors. The static stretches for these muscle groups were performed separately on each leg. In the no stretch (NS) condition, participants sat quietly for 20 minutes before beginning the WAnT protocol.

Participants then completed a 10 minute warm up of at least 50 rpm and a resistance of 50 watts (W) on the CompuTrainer™. Feedback such as "you need to ride a little faster" or "you need to pedal a little slower" was used in order to ensure the participant was pedaling at least 50 rpm. Following this warm up session, the CompuTrainer™ was calibrated per manufacturer's instructions. Upon completion of the warm-up, the participant completed a two minute cool down and rest before beginning the WAnT. Upon completion of the warm-up and before the WAnT began, participants received an explanation of the test. After the test was initiated, the participant received verbal feedback from the researchers to encourage maximum effort throughout the WAnT protocol.

The WAnT was completed using an electronically-braked ergometer (Racermate, Seattle, Washington, USA), and all conditions were computer controlled. Each participant was instructed prior to each trial, using a written script (Appendix 4 & 5). For both trials, the participants had pedal straps placed over their feet to avoid foot misplacement during the test. Further, the participants were instructed to place their hands on the top portion of the handlebar, which was parallel with the ground. Along with instructions for the test's procedure, it stated: "The test will require you to pedal as hard and fast as you are able throughout the entire test. Please pedal with your smoothest, most efficient cycling cadence and form throughout." The proprietary software applications of the Computrainer™ measured the gross motor coordination of pedaling. During the test, SpinScan (SS), Average Torque Angle (ATA), cadence or revolutions per minute (RPM), wattage (W), and the percentage of bilateral efficiency of the legs was recorded via the CompuTrainer™. The participant's heart rate (HR) was also recorded every second using the CompuTrainer™ system, through its interface with the widely available Polar heart rate monitor (Polar, Lake Success, NY, USA). Authors have found the Polar heart rate monitor to be valid and reliable.[43,44]

Data Analysis

Data collected was entered into a data analysis software application (Excel, Microsoft Corporation, Redmond, Washington) and configured for statistical analysis. All data collected in this study used standard methods to ensure the confidentiality of participants. Code numbers were used to de-identify the participants, and the master code was stored as a separate document on a password protected computer maintained by WKU. Data collection sheets (Appendix 8) identified participants solely by number, as did computer files containing data on the dependent variables included in this study (Appendix 9).

Statistical analysis was conducted using SPSS 21.0 (IBM SPSS, Armonk, New York). Independent variables included stretching condition (static stretching versus no stretching). Dependent variables used to assess GMCP included the following measures collected continuously during each WAnT: speed, watts, rpm, % power (% left vs right lower extremity), average torque angle (ATA), and SpinScan™ (SS). Repeated measures analysis of variance was conducted on each of these variables as a means of assessing the impact condition (STST vs. NS) over time. In addition, paired t-tests and correlational analyses were conducted to assess the impact of condition upon measures of peak power (PP), mean power (MP), minimum or low power (LP), and fatigue index (FI). Each of these measures were calculated using 5 second intervals, as previously described.[23] Fatigue index was calculated using the following equation:

FI: [(Peak Power Output – Min Power Output)/Peak Power Output)] x 100[23]

Significance for all statistical testing was set at the $p \leq 0.05$ level.

CHAPTER 3

RESULTS

Significant and non-significant differences were found for the variables used in this study. Significant differences were found between conditions for the entire 30 seconds of the WAnT for Combined SS (F (1, 27) =5.346, $p \leq 0.029$) and Left SS (F (1, 27) =6.508, $p \leq 0.017$). Significant differences (F (5, 23) =42.99, $p \leq 0.001$) were found for all dependent variables over time for the 30 second time frame. Post-hoc analyses of the data for the entire 30 second duration of the WAnT revealed that differences between conditions were most evident early in the performance of the WAnT. In post-hoc analysis, significant differences were found during the first 10 seconds of the WAnT for left SS (F (1, 27) =7.345, $p \leq 0.012$) and left ATA (F (1, 27) =4.332, $p \leq 0.047$), as well as non-significance for SS (F (1, 27) =4.110, $p \leq 0.053$). In the post-hoc analysis upon the first 10 seconds of the test, significant differences (F (1, 27) =24.248, $p \leq 0.001$) were found for all dependent variables of time from 0 to 10 seconds on the WAnT. The findings are depicted in Table 3 and shown graphically in Figures 1 through 5.

Non-significant differences were found between conditions (static stretching versus control) for measures of PP (t (27) = -1.124, $p \leq 0.271$), MP (t (27) = -1.298, $p \leq 0.205$), LP (t (27) = -.793, $p \leq 0.435$), and FI (t (27) = -3.28, $p \leq 0.745$). Each dependent variable was also significantly correlated between the two conditions: PP (r = .688, $p \leq$

0.001), MP ($r = .802$, $p \leq 0.001$), LP ($r = .808$, $p \leq 0.001$), and FI ($r = .593$, $p \leq 0.001$).

These findings are described more fully in Table 4.

CHAPTER 4

DISCUSSION

The findings in the present study show that STST produced both statistically significant and clinically meaningful effects upon GMCP measures during vigorous cycling, as the static stretching versus no stretching condition had an impact on GMCP measures assessed in this study. In the STST condition, participants exhibited statistically-significant decreased values in the Combined SS and Left SS values. Researchers have described the SS as a composite measure of pedaling efficiency while cycling. [45] Participants also produced decreased values for cycling speed (km/hr), power output (watts), cadence (rpm) and average torque values during the WAnT protocol that followed the STST protocol. While these particular findings were not statistically significant, they likely have clinical meaningfulness. For example, cycling coaches with access to this information may not encourage their athletes to engage in static stretching prior to maximal sprint activity or racing heats. Still, more research is needed to better understand the ways in which STST may negatively influence GMCP measures during vigorous cycling.

The present findings are consistent with many studies suggesting STST negatively influences force production measures during short-duration, high-intensity activities. A number of papers have reported reduced muscular force production immediately following a STST session. Authors have reported STST produced decreased muscular performance measures for one repetition maximum (1-RM) leg press, knee-extensor concentric torque, 20-m sprint performance, and magnitude of vertical jump height.[46,47,48,49] A consistent characteristic of such studies is the completion of a high intensity, short duration activity within a few minutes after participants execute a STST regimen. Thus, the present findings might support these earlier reports of diminished muscular force production following a bout of STST, as alterations in GMCP could be attributed to force production changes.

Evaluation of the GMCP variables showed that the differences between stretching and non-stretching conditions were most evident during the first 5-10 seconds of the WAnT. This difference may be due to the ATP-PCr energy system that predominates during the first few seconds of exercise. In short, STST may negatively influence the ATP-PCr system in some subtle way. An example of this can be seen in Figure 1 when more watts of power were produced during the beginning of the non-stretching condition. Authors have also attributed lesser force production following STST to factors such as stress relaxation of the muscle tissue, which leads to lower muscle-tendon stiffness and strength [50], or peripheral nervous system inhibition that results in lesser muscle activation [48]. Either of these factors may be at play in the present study, and may help to explain the differences in GMCP demonstrated for the full 30 second duration of the WAnT. Further study is needed to provide insight on how these and other factors may contribute to changes in GMCP following STST.

In regards to the power and fatigue measures collected during the short-term physical activity, the findings show that they were not negatively influenced by STST.

Each of these factors are important considerations in sport biomechanics, as it stands to reason either is capable of altering performance during high-intensity, short-duration activities such as the WAnT. However, the lack of non-significant differences between stretching conditions suggest that neither of these mechanisms led to differences in PP, MP, LP, or FI in this study. Similarly, while measures of fatigue over a 30 second period represent a longer time frame than the following studies, the present findings do not support previous reports that STST produced decreased measures of muscular performance during one repetition maximum (1-RM) leg press, knee-extensor concentric torque, 20-m sprint performance, and jumping performance.[46,47,48, 49] In short, the present findings do not support previous reports that STST negatively affects many measures of short duration, high intensity muscular performance.

These results are consistent with previous studies that investigated the influence of STST upon cycling bouts of longer duration. Similar to the present study, Wolfe et al. found no differences in VO_2 measures between STST and NS conditions during the final 25 minutes of a submaximal cycling protocol [51]. But they did find an effect of STST on cycling economy, reporting a decrease in cycling economy measures during the first 5 minutes of a submaximal VO_2 test following a STST regimen. These authors speculated that this decreased economy could be attributed to alterations in muscle mechanics, neural factors, or a combination of the two. They further speculated that STST may place motor units in a fatigued state. By fatiguing motor units, there may be a decreased number of available motor units recruited to produce force or the recruited motor units may simply produce less force. Nonetheless, the fatigue measures used in this study did not appear to be negatively influenced by STST.

The present findings also do not support a study by Fowles et al., which showed that STST can decrease force production and muscle tendon stiffness for up to one hour [52]. It is possible that the 10 minute warm up ride completed between the STST and NS conditions attenuated in some way the potential impact of STST on fatigue measures. Future study might include repeating this same study, differing only in the removal of the 10 minute warm up ride; doing so might provide additional insights into ways that STST does, or does not, impact measures of fatigue. Similarly, future study might assess the impact of STST on WAnT performance on experienced cyclists, as they may respond to this condition differently than did the novice cyclists completing this study.

Strengths of the present study include its treatment of a topic which broadens the spectrum of activities that have been assessed following STST, as few studies have investigated the impact of STST upon performance measures during cycling in general or the WAnT in particular. Similarly, while much is known about the impact of STST on muscular force production, little is known about the ways in which STST may influence biomechanics or GMCP. As it has been linked to musculoskeletal injuries such as those to the ACL, this area is an important consideration given the role of force production in the creation and control of coordinated motor activity. For example, this type of research can help coaches better train athletes so as to improve athletic performance and decrease odds of injury, or help physical therapists better understand the cause of injury due to repetitive motion, which is an important consideration when constructing any rehabilitation programs. A limitation of the present study is the delimitation of the participants to apparently healthy young women. They may have responded to STST in ways inconsistent with other populations.

Consequently, future study should investigate the impact of STST on GMCP among other physically active populations. This research may include the comparison between GMCP due to dynamic stretching, variance of fine motor coordination patterns (FMCP) due to static or dynamic stretching, comparisons between males vs. females, and even further study of GMCP relating to static stretching. As research on this topic begins to expand, individuals will begin to better understand the effects of different stretching techniques on various motor coordination patterns and can, in turn, develop safer ways to train athletes and prevent injury in all populations.

CHAPTER 5

CONCLUSION

Previously, few studies have been conducted on the effects of STST on GMCP. Authors have, however, linked both GMCP and fatigue to musculoskeletal injuries, and STST to decreased performance measures. As such, these results have both scientific and clinical value as the first known investigation on the effects of STST on fatigue characteristics during vigorous cycling activity.

Participants demonstrated decreased laboratory measures of GMCP following the completion of the STST protocol done prior to the WAnT when compared to a no-stretching condition. Additionally, participants demonstrated no significant differences in fatigue or power measures following STST. Thus, the present study did partially support the previous papers detailing STST prompting decreased measures for many sport activities fueled by anaerobic metabolism. These findings may help sport scientists better understand the impact of stretching methodologies in improving performance and preventing injury and make better use of static stretching routines in training and rehabilitation.

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APPENDIX

Table 1: Schematic Representation of Repeated Measures Design

First Data Collection Session

Counterbalanced Design

Static Stretching **Vs** **No Stretching**

Second Data Collection Session

Remaining Condition (Static Stretching vs No Stretching)

Followed by WAnT Protocol

Table 2: Inclusion/Exclusion Criteria

Inclusion

- Must be a non-cyclist
- Participants must have regular exercise routine (30 minutes, 3 days per week, for a period of at least 3 months)
- Female individuals 18-30 years
- Ability to transport independently to our exercise lab at various times during the day, making concessions with class or work schedule

Exclusion

- ACSM cardio risk factors (high risk ,which equates to 1 or more of the following signs/symptoms OR known cardiovascular, pulmonary, and/or metabolic disease)
    - Pain, discomfort, (for other angina equivalent) in the chest, neck, jaw, arms, or other areas that may result from ischemia
    - Shortness of breath at rest or with mild exertion
    - Dizziness or syncope
    - Orthopnea or paroxysmal nocturnal dyspnea
    - Ankle edema
    - Palpitations or tachycardia
    - Intermittent claudication
    - Known heart murmur
    - Unusual fatigue or shortness of breath with usual activities
- Neuromuscular condition
- Lower extremity or back injuries impairing cycling abilities (including surgery within the past year or an injury within the past 6 months)
- Presents risk for coronary artery disease, pulmonary pathology (either obstructive or restrictive, including exercise induced asthma)

Table 3. Results of the Analysis of Variance (ANOVA). Comparison of dependent measures by condition.

Condition (n=28)	**Stretch Mean±SD**	**No Stretch Mean±SD**	**F score**	**P value**
Speed	18.69±.372	19.28±.283	2.406	.133
Watts	365.12±10.79	383.43±9.06	1.702	.203
RPM	18.69±.372	19.26±.283	2.406	.133
SpinScan	68.6±.647	70.58±.974	5.346	.029*
Left SpinScan	67.14±.783	69.99±.981	6.508	.017*
Right SpinScan	69.54±.631	70.68±1.063	3.110	.089
Left Power	49.88±.287	49.67±.326	4.119	.052
Right Power	50.12±.287	50.26±.331	3.436	.075
Left Average Torque Angle (LATA)	105.14±.687	103.12±.757	1.749	.197
Right Average Torque Angle (RATA)	99.64±.562	99.57±	.066	.799

* statistically significant, $p \leq 0.05$

Table 4. Results of the paired t-tests. Comparison of power measures by condition.

Condition (n=28)	Stretch Mean±SD	No Stretch Mean±SD	F score	P value	Correlation	P value
Peak Power (PP)	396.17±51.24	404.95±53.32	-1.124	0.271	.688	0.000*
Mean Power (PP)	305.02±34.28	310.48±36.35	-1.298	0.205	.802	0.000*
Low Power (LP)	233.85±37.10	237.12±37.10	-.793	0.435	.808	0.000*
Fatigue Index (FI)	40.37±10.15	40.89±7.87	-3.28	0.745	.593	0.001*

* statistically significant, $p \leq 0.05$

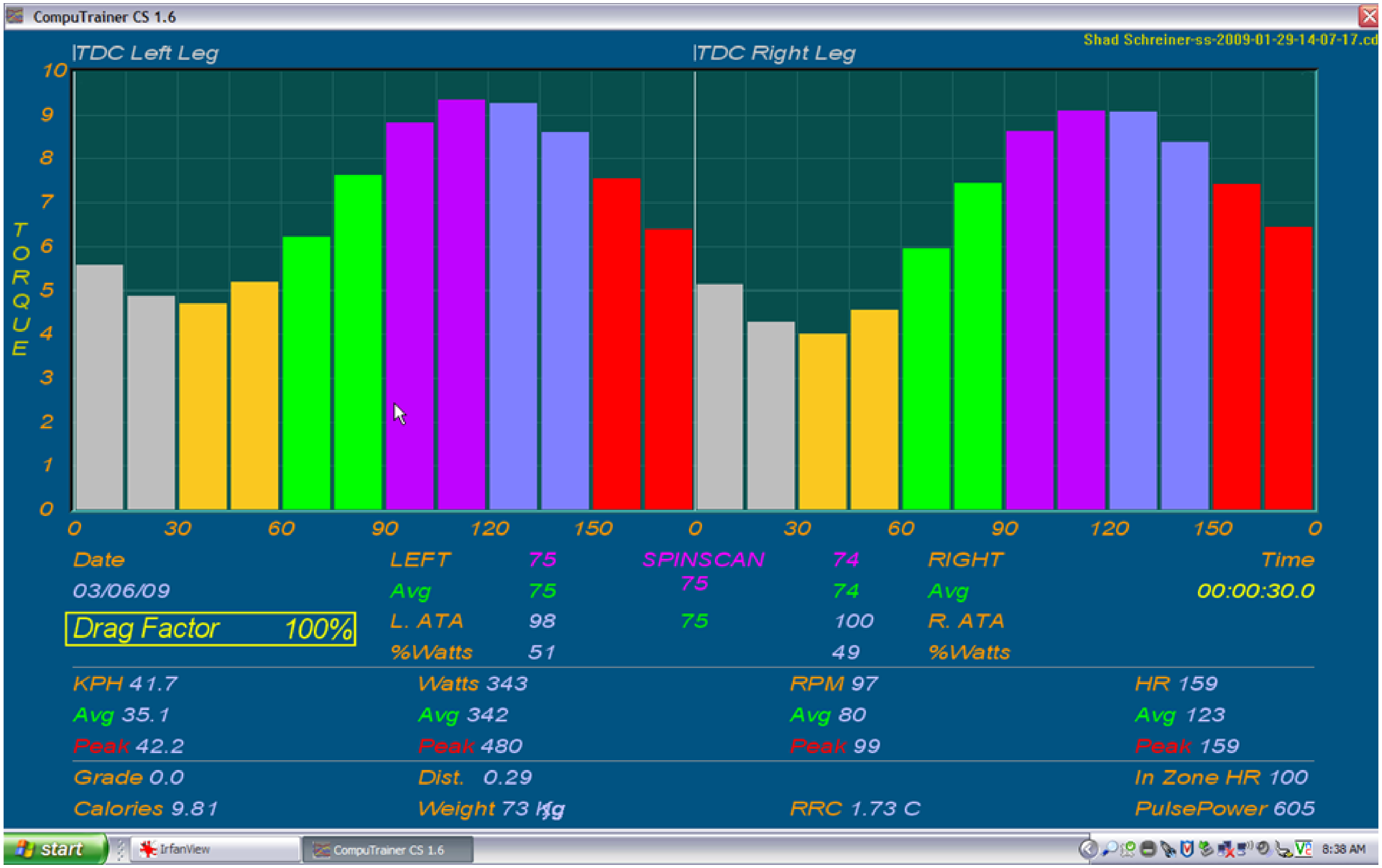


Figure 1.1 Composite measures of gross motor coordination patterns (GMCP) while cycling.

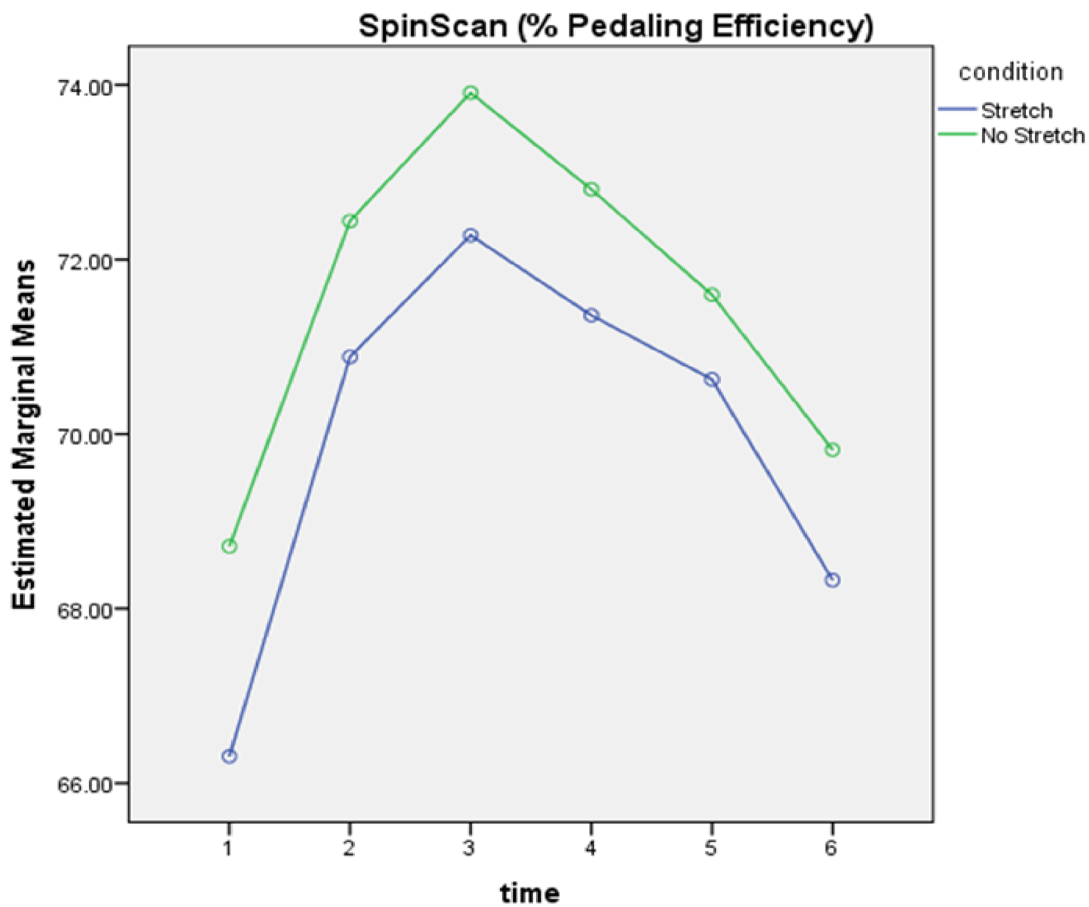


Figure 1.2 Significant differences ($p \leq 0.05$) between conditions and over time for Combined SpinScan™.

Analysis of estimated marginal means (n=28).

Figure 1.3 Significant differences ($p \leq 0.05$) between conditions and over time for Left SpinScan ™ . Analysis of estimated marginal means (n=28).

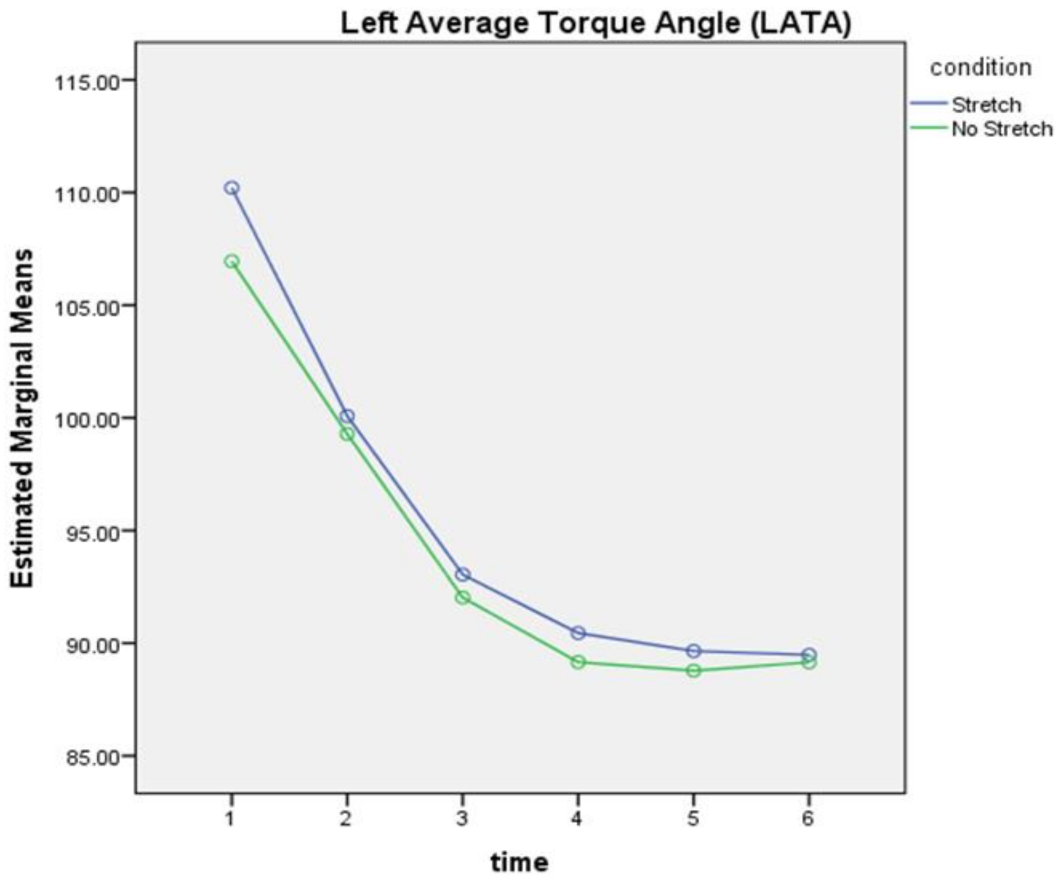


Figure 1.4 Significant differences ($p \leq 0.05$) between conditions for LATA during first 10 sec of WAnT. Analysis of estimated marginal means (n=28).

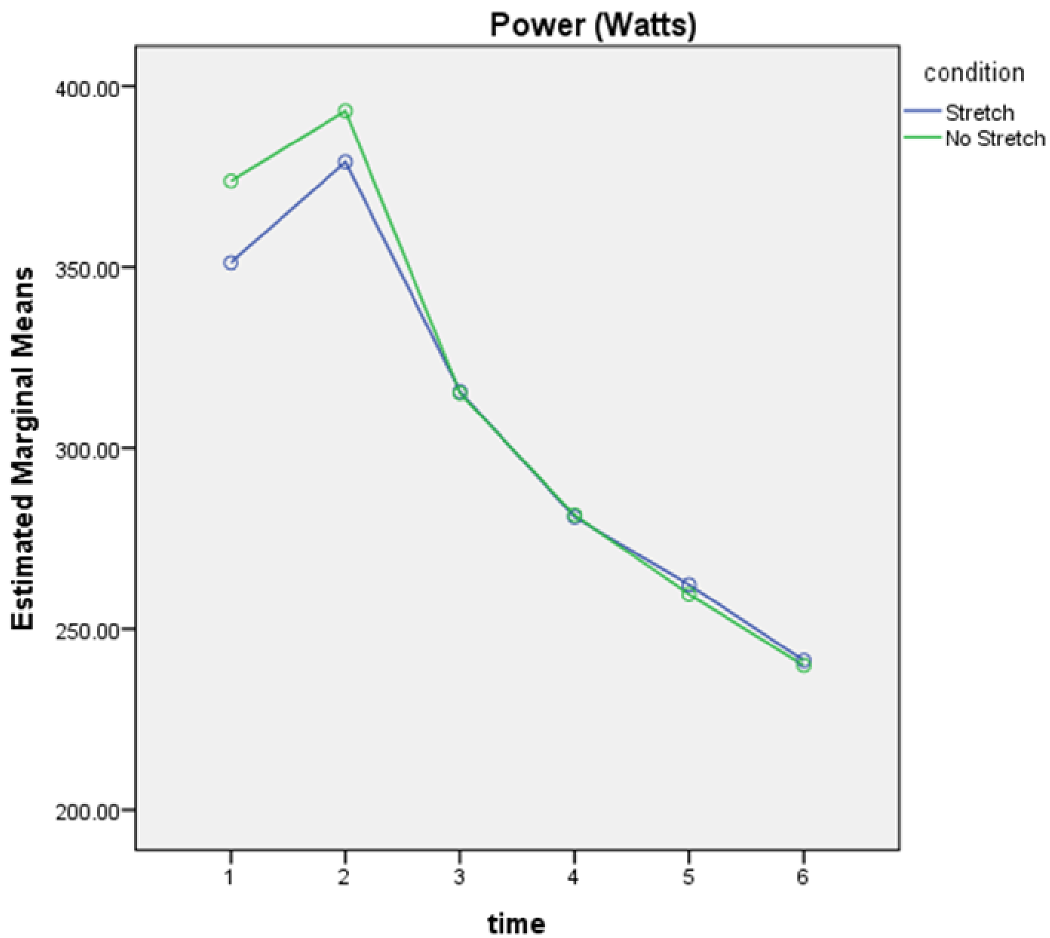


Figure 1.5 Significant differences ($p \leq 0.05$) over time for power output. NSD between conditions. Analysis of estimated marginal means (n=28).

Call for Participants

DOCTOR OF PHYSICAL THERAPY

Seeking Young Adults for Research Study

Are you interested in the profession of physical therapy?
Would you like to know how static stretching before physical activity affects exercise performance?
Are you a physically active 18-30 year old woman?

If you answered YES to any of these questions, you may qualify for participation in our latest research study:

Faculty and students in the Doctor of Physical Therapy Program at Western Kentucky University are conducting a research study investigating the influence of static stretching on coordination during vigorous physical activity.

- Participants will be expected to travel to Tate Page Hall at Western Kentucky University to take part in this study.
- Individuals will visit the laboratory on two occasions for approximately 30 minutes each.
- Participants will engage in approximately 15 minutes of cycling per session and complete two power tests

Criteria for the Study

Participants must be:

- Women between the ages of 18 to 30
- Non-cyclist
- Physically active, participating in a regular exercise routine (30 minutes, 3 days per week, for a period of at least 3 months)

<u>If interested please contact:</u>

Stephanie Gaiko
270-535-8035
Stephanie.gaiko907@topper.wku.edu

Paige Volpenhein
859-630-2098
paige.volpenhein536@topper.wku.edu

Medical Screening Form

Medical Screening Form

Please complete the following questions to the best of your ability

PATIENT INFORMATION

Name:____ Date of Birth:______________________

Telephone #:_________________________________ Gender: M________ F_______ Height: ______ Weight: _______

Emergency Contact Name: ____________________________________ AND Tel #: ________________________

MEDICAL HISTORY (Explain "yes" answers below. Circle questions for which you don't know answers to.)

	Yes	No
a) Have any close relatives (<50 years of age) ever experienced:		
a. Premature death (sudden or otherwise) from cardiovascular disease	☐	☐
b. Premature morbidity or disability from cardiovascular disease	☐	☐
c. Specific knowledge of:		
1) Hypertrophic cardiomyopathy	☐	☐
2) Dilated cardiomyopathy	☐	☐
3) Long QT syndrome	☐	☐
4) Marfan's syndrome	☐	☐
5) Clinically important arrhythmias	☐	☐

b) Have you ever been told you have **OR** experienced any of the following conditions?

	Yes	No		Yes	No
Diabetes	☐	☐	Heart Murmur	☐	☐
High Blood Pressure	☐	☐	Chest Pain	☐	☐
High Cholesterol	☐	☐	Dizziness	☐	☐
Shortness of Breath	☐	☐	Palpitations/racing heart	☐	☐
Persistent pain at night	☐	☐	Arthritis	☐	☐
Numbness/tingling	☐	☐	Current smoker or quit within last 6 months	☐	☐
Problems with balance/falling	☐	☐	Swelling in legs or ankles	☐	☐
Unexpected weight loss	☐	☐	Any other health concerns	☐	☐

Please explain: ____

____

c) Have you ever fainted during or after exercise?
d) Have you ever been dizzy during or after exercise?
e) Have you ever had chest pain during or after exercise?
f) Have you ever had excess shortness of breath during or after exercise?
g) Do you use more than 1 pillow under your head to sleep at night?
h) Do you ever wake up short of breath?
i) Have you ever had pain or cramping in your legs during exercise?
j) Do you use an assistive or prosthetic device?

k) Please list any surgeries or other conditions for which you have been hospitalized in the last five years, including the date and reason for the surgery or hospitalization.

DATE REASON FOR SURGERY/HOSPITALIZATION

____

____

l) Please list any **over-the-counter** and **prescription** medications that you are currently taking.

____

____

m) What is your current physical activity level? (Please include type of activity and frequency)

____

Participant's signature ____ Date ___________________

Witness's signature ____ Date ___________________

Letter of Informed Consent

Note: Letter of Informed Consent to be printed on letterhead for Doctor of Physical Therapy Program, Western Kentucky University

Co-Principal Investigators: Stephanie Gaiko and Paige Volpenhein
Supervising Investigators: Donald Hoover, PT, Ph.D., CSCS and Scott Arnett PhD
School/Department/Division: Doctor of Physical Therapy Program, Western Kentucky University
Telephone: 270-745-4378
Email: don.hoover@wku.edu

INFORMED CONSENT FOR PARTICIPATION IN RESEARCH ACTIVITIES

THE EFFECTS OF STATIC STRETCHING ON MEASURES OF GROSS MOTOR COORDINATION DURING VIGOROUS PHYSICAL ACTIVITY

1. PURPOSE OF THIS RESEARCH STUDY: The purpose of this study is to assess the effects of static stretching on gross motor coordination patterns during vigorous physical activity via a standardized cycling test known as the Wingate Anaerobic Test (WAnT). My participation in this study is expected to include two sessions lasting no more than 45 minutes. I understand that I will be one of approximately thirty persons participating in this study.

2. WHAT WILL BE DONE / PROCEDURES: Before I participate in any physical activity, I will undergo a health examination to reveal coronary artery disease risk factors along with signs/symptoms of cardiovascular, pulmonary, and/or metabolic disease. The aim of this screening is to minimize risk to participants and to determine my suitability for inclusion in this study. Each component of this screening will be explained to me, and I will have an opportunity to have my questions answered. This, and all testing that will follow, will take place in the Human Performance Laboratory in the Doctor of Physical Therapy Program located on the campus of Western Kentucky University.

   If I meet the inclusion criteria, members of the research team will begin to collect relevant physiological and biomechanical data during two laboratory sessions. This session will occur at a time agreed upon by both researcher and participant. The testing will include two short bouts of intense cycling the order of each these tests will be determined by a coin toss and completed over the two laboratory sessions. I understand that each session is expected to last approximately 45 minutes or less.

3. POSSIBLE BENEFITS: I recognize that I may gather possible personal benefits including increased knowledge regarding my gross motor function. I also recognize I have been informed that my participation in this research may not benefit me or my health. Potential benefits to others may result from the knowledge gained from my participation in this research study. I have been informed that my decision to participate, refuse to participate,

decision to withdraw from the study will not adversely affect me in any way. I understand that individuals are not being compensated in any way for participating in this study.

4. <u>POSSIBLE RISKS AND DISCOMFORTS:</u> I recognize the risks of participating in this study are minimal. Potential risks and discomforts of this study are fatigue, delayed-onset muscle soreness (DOMS), muscular injury, shortness of breath in response to physical activity, and localized fatigue. Sudden cardiac death is a potential risk with any form of exercise, however the inclusion and exclusion criteria listed above was crafted to mitigate this risk. I also recognize that I must mark my index finger with black ink for one of the power tests, and I understand that cleaning materials will be available help me clean my hand upon completion of the test.

5. <u>CONFIDENTIALITY OF RECORDS</u>: I understand any information acquired from this study in which I might be identified will remain confidential. All printed records will be stored in a locked file cabinet in a locked room; digital files and other software application files related to my participation in this study will be stored on computers maintained by Western Kentucky University. Only the investigator and members of the research team will have access to these records, and all records related to my participation will be destroyed after final presentation or publication of the results of this study. If information learned from this study is published, I will not be identified by name. By signing this form, however, I allow the research study investigator to make my records available to the Western Kentucky University Institutional Review Board (IRB) Office and regulatory agencies as required by law.

   I understand that although my confidentiality in this study is protected, this confidentiality may not be absolute or perfect. There are some situations where research staff may be required by law to share information that I have provided.

6. <u>OFFER TO ANSWER QUESTIONS AND RESEARCH INJURY NOTIFICATION</u>: Dr. Don Hoover, or a colleague of Dr. Hoover responsible for this research study, has answered my questions regarding my participation in this research study. I understand that if I have any further questions, I can contact Dr. Hoover at (270) 745-4378. I understand that I will receive a copy of this informed consent document for my records.

   I understand that if I experience an injury that is related to my participation in this study, I should contact Dr. Hoover at (270) 745-4378.

7. <u>EXPLANATION OF TREATMENT AND COMPENSATION FOR INJURY</u>: I recognize if I sustain an injury as a direct result of my participation in this research, I should obtain medical care in the same manner as I would ordinarily obtain treatment. I understand that no provision has been made for financial payments or other forms of compensation (such as lost wages, medical cost reimbursement, lost time, or discomfort) with respect to such injuries. I recognize I am not waiving any of my legal rights by signing this consent form.

8. VOLUNTARY PARTICIPATION WITH RIGHT OF REFUSAL: I have been informed that my participation in this research study is voluntary. I am free to withdraw my consent for participation in this study at any time without penalty.

9. IRB REVIEW AND IMPARTIAL THIRD PARTY: This study has been reviewed and approved by the Institutional Review Board (IRB) at Western Kentucky University. A representative of that Board, from the IRB Office, is available to discuss the review process or my rights as a research subject. The telephone number of the Western Kentucky University IRB Office is (270) 745-4211.

10. SIGNATURE FOR CONSENT: The above-named investigator has answered my questions and I agree to be a research subject in this study.

____________________	____________________	______
Research Participant's Name	Research Participant's Signature	Date
____________________	____________________	______
Investigator's Name	Investigator's Signature	Date

Instructions for Performance Testing Session 1

Stretching vs. Non-Stretching Script:

“Each participant will follow the stretching protocol or sit for 16 minutes as determined by the randomized study design. When the stretching protocol is to be used, participants will be verbally instructed how and which muscle to stretch for 30 second repetitions. When the non-stretching protocol is to be used, participant will be instructed to sit and relax for 16 minutes.”

Participant’s test order for SS versus NS condition is determined by counterbalanced design. Refer to counterbalance worksheet to determine whether stretching will be performed before the first or second trial. If stretching protocol is determined, take participant through the stretching protocol detailed in Appendix 7. If no stretching protocol is determined, have participant sit in chair for 16 minutes.

WAnT Preparation Script:

“Today’s exercise session will include a 30 second Wingate anaerobic test (WAnT), which is performed on the bike in the sitting position. Please tell us if you experience any discomfort or wish to stop the test. Physiological values will be taken during this time frame. We will now measure your height, weight, and bike seat height and flip a coin to see which trial you will participate in today.”

Participant’s height, weight, and inseam are measured. The bike seat height is determined by the participant’s inseam measurement (inches) multiplied by 1.09. Apply this measurement from the top of the pedal at its lowest point to the top of the bike seat. Flip a coin to determine whether stretching will be performed before the first or second trial.

Set the Germania 0.5 course on the Computrainer™.

WAnT Script:

“You will warm up on the bicycle for ten minutes, pedaling at a comfortable pace of 50 rpm. We will take physiological measures of your performance throughout this time frame. At the ten minute mark, you will rest for two minutes before we begin the formal testing. Today’s exercise session will consist of one 30 second trial. Place your hands on the top portion of the handle bar and your feet in the pedal straps. You will then begin by pedaling as fast as possible with no resistance during the three seconds countdown to reach your full pedaling speed. At the end of the countdown, the set resistance will be added. The test will require you to pedal as hard and fast as you are able the ensuing 30 seconds. Please pedal with your smoothest, most efficient cycling cadence and form the entire 30 seconds. This test may be uncomfortable. If at any point you feel like you cannot continue, the test will be terminated. You will cool down for two minutes after the WAnT. Are you ready to

start the test?"

Begin the warm up, monitoring that the participant pedals at a 50 rpm cycling cadence pace with no additional resistance for ten minutes. At the ten minute mark, allow the participant to rest for two minutes. Begin the three second countdown and allow the participant to complete the WAnT. Monitor SS, RPM, ATA, W, the percentage of bilateral efficiency of the legs, and the heart rate. Upon completion of the WAnT, instruct the participant to cool down for at least two minutes on the bicycle. Participant's resting heart rate, blood pressure, and respiratory rate will be measured and recorded after the cool down.

Script for Closing First Session:

"You have completed today's trial session. Thank you for coming in today and participating in part one of the study. We look forward to seeing you for part two."

Instructions for Performance Testing Session 2

Stretching vs. Non-Stretching Script:

"Each participant will follow the stretching protocol or sit for 16 minutes as determined by the randomized study design. Today you'll complete the condition that you did not complete during the first data collection session."

Participant's test order for SS versus NS condition was determined by counterbalance design. Take the participant through the protocol not yet completed.

WAnT Preparation Script:

"Today's exercise session will include a 30 second Wingate anaerobic test (WAnT), which is performed on the bike in the sitting position. Please tell us if you experience any discomfort or wish to stop the test. Physiological values will be taken during this time frame. We will now measure your height, weight, and bike seat height and flip a coin to see which trial you will participate in today."

Participant's height, weight, and inseam were measured previously. The bike seat height is determined by the participant's inseam measurement (inches) multiplied by 1.09. Apply this measurement from the top of the pedal at its lowest point to the top of the bike seat.

Set the Germania 0.5 course on the Computrainer™.

WAnT Script:

"You will warm up on the bicycle for ten minutes, pedaling at a comfortable pace of 50 rpm. We will take physiological measures of your performance throughout this time frame. At the ten minute mark, you will rest for two minutes before we begin the formal testing. Today's exercise session will consist of one 30 second trial. Place your hands on the top portion of the handle bar and your feet in the pedal straps. You will then begin by pedaling as fast as possible with no resistance during the three seconds countdown to reach your full pedaling speed. At the end of the countdown, the set resistance will be added. The test will require you to pedal as hard and fast as you are able the ensuing 30 seconds. Please pedal with your smoothest, most efficient cycling cadence and form the entire 30 seconds. This test may be uncomfortable. If at any point you feel like you cannot continue, the test will be terminated. You will cool down for two minutes after the WAnT. Are you ready to start the test?"

Begin the warm up, monitoring that the participant pedals at a 50 rpm cycling cadence pace with no additional resistance for ten minutes. At the ten minute mark, allow the participant to rest for two minutes. Begin the three second countdown and allow the participant to complete the WAnT. Monitor SS, RPM, ATA, W, the percentage of bilateral efficiency of the legs, and the heart rate. Upon completion of the WAnT, instruct the participant to cool down for at least two minutes on the bicycle. Participant's resting heart rate, blood pressure, and respiratory rate will be measured and recorded after the cool down.

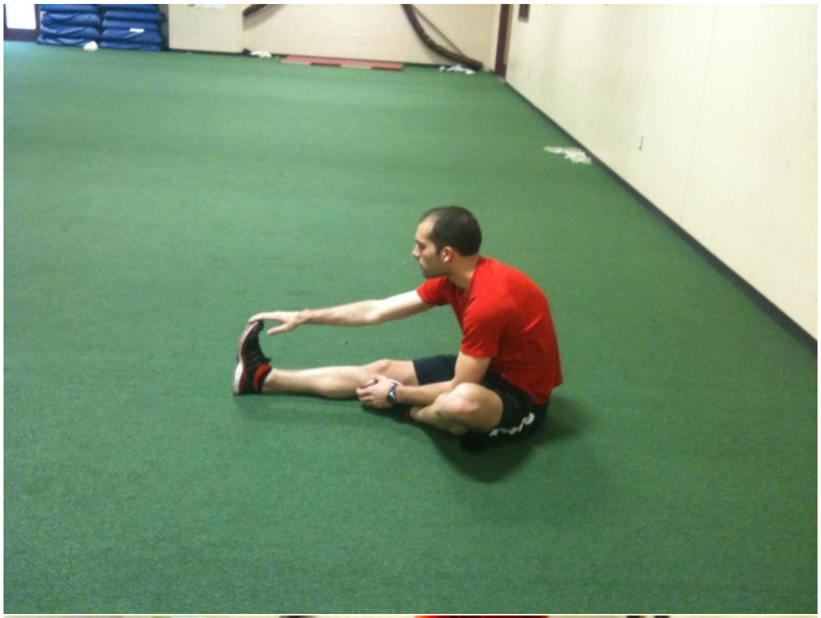
Script for Closing First Session:

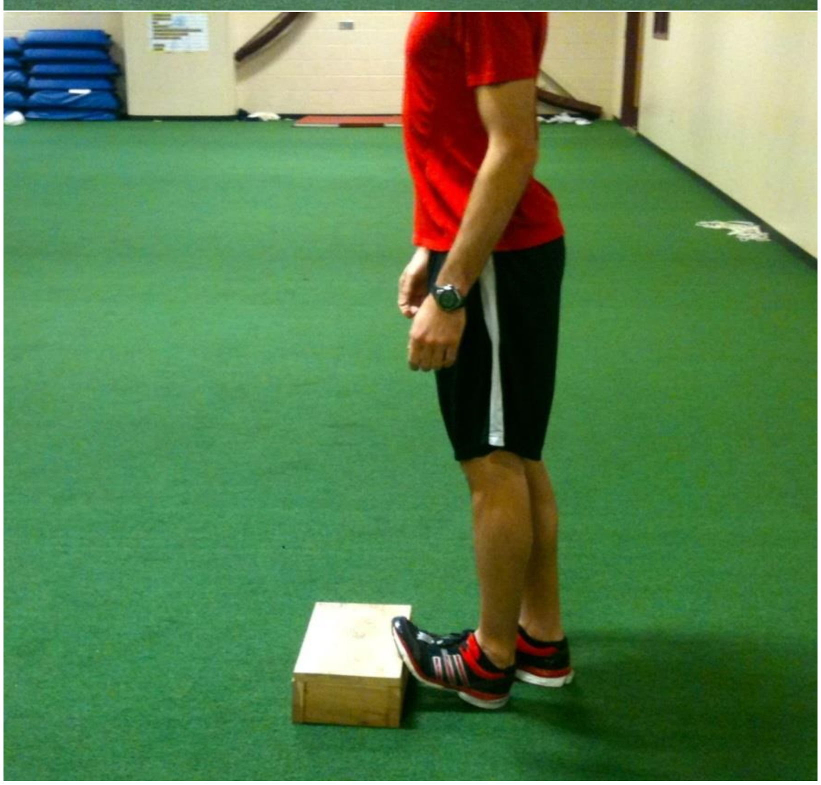
"You have completed today's trial session. Thank you for coming in today and participating in part two of the study. This concludes your involvement in the study. We thank you for helping to make this study possible."

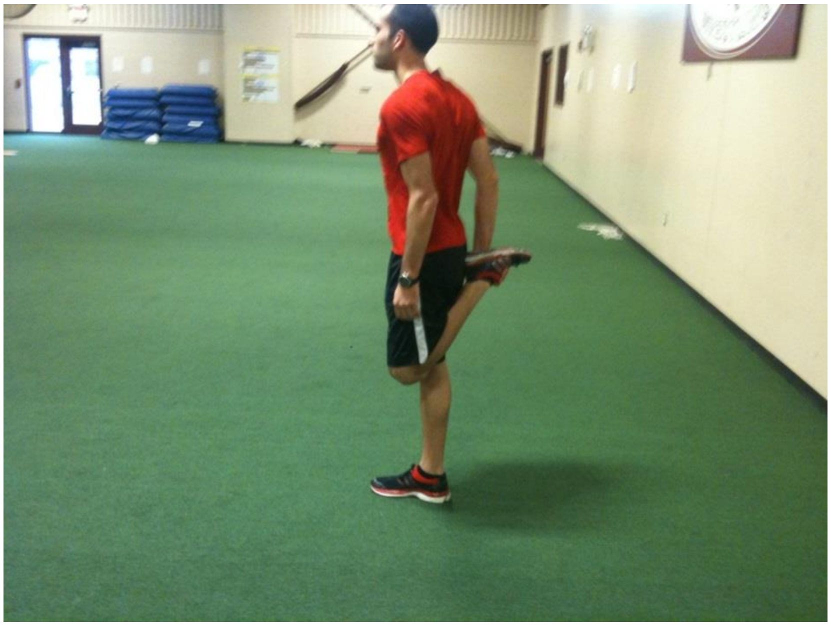
Stretching Protocol

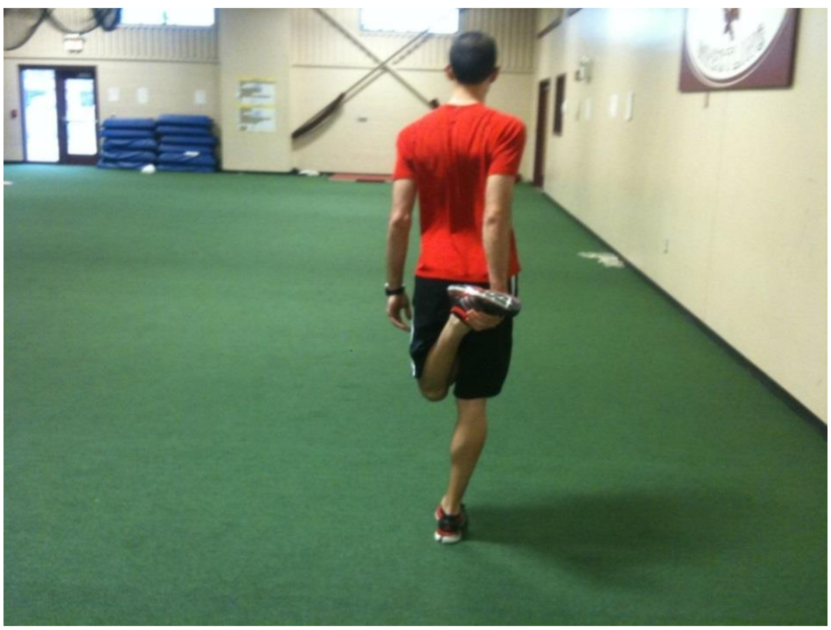
A recent study by Wilson et al.[51] looked at running efficiency with a stretching protocol that was similar to that of Nelson et al.[42] and Egan et al.[53] with a few modifications and a non-stretching control group. The stretching protocol consisted of four, 30-second repetitions each of 5 stretching exercises, which were performed with an average total stretching time of 16 minutes[42]. The following stretches were performed separately on both legs. For the hip extensors and knee flexors, participants performed the sit-and-reach (Image 1), while the plantar flexors were stretched by standing and lowering both heels on the edge of a block (Image 2). For the knee extensor muscles, participants stood on one leg, while grasping the ankle of the opposite leg and pulling their knee joint into flexion until their heel touched their buttocks (Image 3, 4). For the hip flexors, participants moved into a lunge position with 1 knee in contact with the ground, while gently shifting their weight forward until they could feel a stretch of mild discomfort in the hip flexors (Image 5). For the gluteus maximus, participants crossed their left foot over their right knee while clasping their hands behind the right thigh and gently pulling the leg in toward their chest (Image 6). On completion, these stretches were repeated on the opposite side. On non-stretching days, participants sat quietly for 16 minutes before the exercise protocol[42]. The study showed that performance of endurance activities following static stretching is decreased. However, this has seldom been applied to cycling, which like running is also a vigorous physical activity. More research on static stretching in cycling would be beneficial in understanding the role of gross motor coordination in injury patterns during vigorous physical activities.

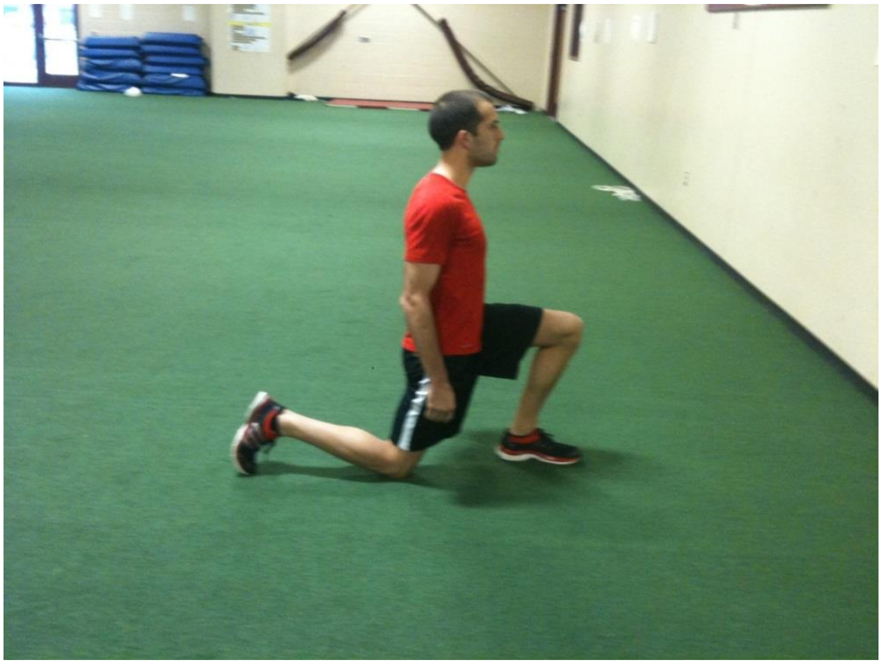
Stretching Routine











Data Collection Sheets

Trial 1: ___________________________________ Condition (circle): SS vs NS

Participant Number: ______________________________ Date: _________________________________

Height (cm): ______________ Weight (kg): _______________ Seat height (cm): ___________________

Resting Vitals

Vital Sign	Pre:	Post:
Heart Rate		
Blood Pressure		
Respiration Rate		

Computrainer: Data included in separate Excel file

Comments: How long ago did she eat? Did the participant successfully complete the trial? How does she feel after the test? Etc?

____
____
____
____
____

Trial 2: ___________________________________ Condition (circle): SS vs NS

Participant Number: ______________________________ Date: _________________________________

Height (cm): ______________ Weight (kg): _______________ Seat height (cm): __________________

Resting Vitals

Vital Sign	Pre:	Post:
Heart Rate		
Blood Pressure		
Respiration Rate		

Computrainer: Data included in separate Excel file

Comments: How long ago did she eat? Did the participant successfully complete the trial? How does she feel after the test? Etc?

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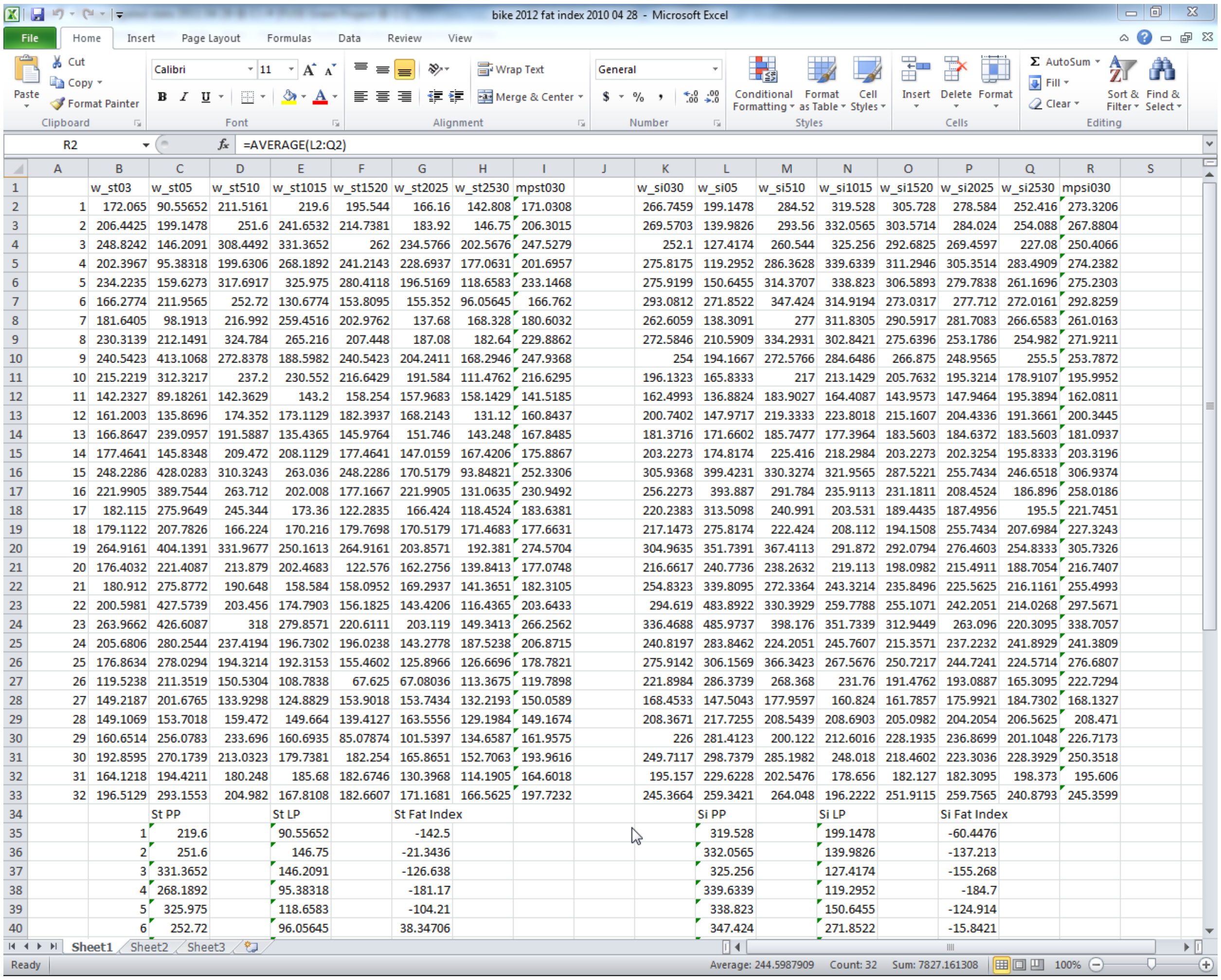
Sample Excel File Depicting Typical Compilation of Dependent Variables Ready for Statistical Analysis



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1		w_st03	w_st05	w_st510	w_st1015	w_st1520	w_st2025	w_st2530	mpst030		w_si030	w_si05	w_si510	w_si1015	w_si1520	w_si2025	w_si2530	mpsi030	
2	1	172.065	90.55652	211.5161	219.6	195.544	166.16	142.808	171.0308		266.7459	199.1478	284.52	319.528	305.728	278.584	252.416	273.3206	
3	2	206.4425	199.1478	251.6	241.6532	214.7381	183.92	146.75	206.3015		269.5703	139.9826	293.56	332.0565	303.5714	284.024	254.088	267.8804	
4	3	248.8242	146.2091	308.4492	331.3652	262	234.5766	202.5676	247.5279		252.1	127.4174	260.544	325.256	292.6825	269.4597	227.08	250.4066	
5	4	202.3967	95.38318	199.6306	268.1892	241.2143	228.6937	177.0631	201.6957		275.8175	119.2952	286.3628	339.6339	311.2946	305.3514	283.4909	274.2382	
6	5	234.2235	159.6273	317.6917	325.975	280.4118	196.5169	118.6583	233.1468		275.9199	150.6455	314.3707	338.823	306.5893	279.7838	261.1696	275.2303	
7	6	166.2774	211.9565	252.72	130.6774	153.8095	155.352	96.05645	166.762		293.0812	271.8522	347.424	314.9194	273.0317	277.712	272.0161	292.8259	
8	7	181.6405	98.1913	216.992	259.4516	202.9762	137.68	168.328	180.6032		262.6059	138.3091	277	311.8305	290.5917	281.7083	266.6583	261.0163	
9	8	230.3139	212.1491	324.784	265.216	207.448	187.08	182.64	229.8862		272.5846	210.5909	334.2931	302.8421	275.6396	253.1786	254.982	271.9211	
10	9	240.5423	413.1068	272.8378	188.5982	240.5423	204.2411	168.2946	247.9368		254	194.1667	272.5766	284.6486	266.875	248.9565	255.5	253.7872	
11	10	215.2219	312.3217	237.2	230.552	216.6429	191.584	111.4762	216.6295		196.1323	165.8333	217	213.1429	205.7632	195.3214	178.9107	195.9952	
12	11	142.2327	89.18261	142.3629	143.2	158.254	157.9683	158.1429	141.5185		162.4993	136.8824	183.9027	164.4087	143.9573	147.9464	195.3894	162.0811	
13	12	161.2003	135.8696	174.352	173.1129	182.3937	168.2143	131.12	160.8437		200.7402	147.9717	219.3333	223.8018	215.1607	204.4336	191.3661	200.3445	
14	13	166.8647	239.0957	191.5887	135.4365	145.9764	151.746	143.248	167.8485		181.3716	171.6602	185.7477	177.3964	183.5603	184.6372	183.5603	181.0937	
15	14	177.4641	145.8348	209.472	208.1129	177.4641	147.0159	167.4206	175.8867		203.2273	174.8174	225.416	218.2984	203.2273	202.3254	195.8333	203.3196	
16	15	248.2286	428.0283	310.3243	263.036	248.2286	170.5179	93.84821	252.3306		305.9368	399.4231	330.3274	321.9565	287.5221	255.7434	246.6518	306.9374	
17	16	221.9905	389.7544	263.712	202.008	177.1667	221.9905	131.0635	230.9492		256.2273	393.887	291.784	235.9113	231.1811	208.4524	186.896	258.0186	
18	17	182.115	275.9649	245.344	173.36	122.2835	166.424	118.4524	183.6381		220.2383	313.5098	240.991	203.531	189.4435	187.4956	195.5	221.7451	
19	18	179.1122	207.7826	166.224	170.216	179.7698	170.5179	171.4683	177.6631		217.1473	275.8174	222.424	208.112	194.1508	255.7434	207.6984	227.3243	
20	19	264.9161	404.1391	331.9677	250.1613	264.9161	203.8571	192.381	274.5704		304.9635	351.7391	367.4113	291.872	292.0794	276.4603	254.8333	305.7326	
21	20	176.4032	221.4087	213.879	202.4683	122.576	162.2756	139.8413	177.0748		216.6617	240.7736	238.2632	219.113	198.0982	215.4911	188.7054	216.7407	
22	21	180.912	275.8772	190.648	158.584	158.0952	169.2937	141.3651	182.3105		254.8323	339.8095	272.3364	243.3214	235.8496	225.5625	216.1161	255.4993	
23	22	200.5981	427.5739	203.456	174.7903	156.1825	143.4206	116.4365	203.6433		294.619	483.8922	330.3929	259.7788	255.1071	242.2051	214.0268	297.5671	
24	23	263.9662	426.6087	318	279.8571	220.6111	203.119	149.3413	266.2562		336.4688	485.9737	398.176	351.7339	312.9449	263.096	220.3095	338.7057	
25	24	205.6806	280.2544	237.4194	196.7302	196.0238	143.2778	187.5238	206.8715		240.8197	283.8462	224.2051	245.7607	215.3571	237.2232	241.8929	241.3809	
26	25	176.8634	278.0294	194.3214	192.3153	155.4602	125.8966	126.6696	178.7821		275.9142	306.1569	366.3423	267.5676	250.7217	244.7241	224.5714	276.6807	
27	26	119.5238	211.3519	150.5304	108.7838	67.625	67.08036	113.3675	119.7898		221.8984	286.3739	268.368	231.76	191.4762	193.0887	165.3095	222.7294	
28	27	149.2187	201.6765	133.9298	124.8829	153.9018	153.7434	132.2193	150.0589		168.4533	147.5043	177.9597	160.824	161.7857	175.9921	184.7302	168.1327	
29	28	149.1069	153.7018	159.472	149.664	139.4127	163.5556	129.1984	149.1674		208.3671	217.7255	208.5439	208.6903	205.0982	204.2054	206.5625	208.471	
30	29	160.6514	256.0783	233.696	160.6935	85.07874	101.5397	134.6587	161.9575		226	281.4123	200.122	212.6016	228.1935	236.8699	201.1048	226.7173	
31	30	192.8595	270.1739	213.0323	179.7381	182.254	165.8651	152.7063	193.9616		249.7117	298.7379	285.1982	248.018	218.4602	223.3036	228.3929	250.3518	
32	31	164.1218	194.4211	180.248	185.68	182.6746	130.3968	114.1905	164.6018		195.157	229.6228	202.5476	178.656	182.127	182.3095	198.373	195.606	
33	32	196.5129	293.1553	204.982	167.8108	182.6607	171.1681	166.5625	197.7232		245.3664	259.3421	264.048	196.2222	251.9115	259.7565	240.8793	245.3599	
34			St PP		St LP		St Fat Index					Si PP		Si LP		Si Fat Index			
35		1	219.6		90.55652		-142.5					319.528		199.1478		-60.4476			
36		2	251.6		146.75		-21.3436					332.0565		139.9826		-137.213			
37		3	331.3652		146.2091		-126.638					325.256		127.4174		-155.268			
38		4	268.1892		95.38318		-181.17					339.6339		119.2952		-184.7			
39		5	325.975		118.6583		-104.21					338.823		150.6455		-124.914			
40		6	252.72		96.05645		38.34706					347.424		271.8522		-15.8421			